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AUTHOR(S):

YEE KWANG, SIM; SHAU-HWAI, AILEEN TAN; YASIN, ZULFIGAR

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The Diversity and Abundance of the Sea Stars (Echinodermata: Asteroidea) from Coral Reefs of the Central South China Sea

SIM YEE KWANG^{1*}, AILEEN TAN SHAU-HWAI² and ZULFIGAR YASIN²

¹Centre For Marine & Coastal Studies (CEMACS), Universiti Sains Malaysia,
11800 Penang, Malaysia

²School of Biological Sciences, Universiti Sains Malaysia,
11800 Penang, Malaysia.

Corresponding author's e-mail: mrsimyk@yahoo.com

Abstract This research was conducted to determine the abundance and diversity status of the sea stars from the central South China Sea. An account is given of the species collected during The Research on the Seas and Islands of Malaysia (ROSES) Expedition 2004 from Archipelago of Beting Patinggi Ali to Pulau Layang-Layang, South China Sea. Fifteen reefs were surveyed in Malaysian waters. Surveys for sea star abundance and diversity were done using SCUBA diving and reef walks at low tide. High abundance and species richness was observed. In total, 6 families, 12 genera and 20 species of sea stars were recorded at the study sites. The most dominant family was Ophidiasteridae (12 species) and the most common genus was *Linckia* spp. (four species). Terumbu Siput (Erica Reef) exhibited the highest diversity of sea stars amongst all the reefs surveyed in this expedition. Ten colour patterns and variations of *Culcita novaeguineae* were observed and specific to each sampling location. Entire sea star species observed in this study was first time recorded in Central South China Sea. Most of the species (18 species) observed during this expedition have been recorded elsewhere in the Indo-Pacific, an indication of the successful larval dispersal along the waters of the South China Sea meanwhile two species are new in South China Sea records, namely *Fromia* sp. and *Leiaster* sp.

Key words: Sea star, Asteroidea, diversity, abundance, coral reef, Central South China Sea

Introduction

Sea stars are generally characterized by a flattened body which tapers into the arms. Sea stars usually have five arms; however a few species have more or less. The arms are generally triangular in shape and originate from the central disk. Others, like the cushion star, *Culcita novaeguineae*, have reduced arms giving the body a pentagonal appearance. The regeneration rate of lost arms is high. In some species, such as from genus *Linckia*, a new animal can be regenerated from a single arm if a portion of the central disc is included (Fell, 1959). The mouth is located on the ventral surface of the central disc. The anus, if present, is found on the upper surface of the disk. Several rows of podia extend from the mouth down each arm. They are used to capture food and for locomotion. There are about 1,800 known species of sea stars, ranging in diameter from approximately 0.05 to 1 meter between opposite arm tips (Sabine, 2000).

There is not much recent publication and information about the taxonomy and distribution of the sea stars in Malaysian waters. The information of the total numbers of sea star species and the distribution pattern in Central South China Sea is still unknown although Purwati & Lane (2004) indicated that total sea star count for the South China Sea as a whole now stands at 230. A comprehensive review and analysis of the literature on echinoderm records for the South China Sea was done by Lane *et al.* (2000) indicates that 227 sea star species were found and their distributions are tabulated therein. 27 sea star species belonging to 9 families have been identified from material

collected in the Anambas and Natuna Archipelagos (Southern South China Sea) during The Anambas Expedition 2002 (Purwati & Lane, 2004). Andrea & Antonella (2003) recorded 21 species (14 genera) with one unidentifiable species (*Penaceraster* sp.) in the guide book of Underwater Malaysia Macrolife (Andrea & Antonella, 2003). A total of 22 species (15 genera) from eight families of sea stars was found in Mindoro, Samar, Palawan and Leyte Island, Camotes Sea, the Philippines (Sabine, 2000). Only five species of sea stars were recorded by Elizabeth & Michael (2002) in the South China Sea. A total of 60 species of sea stars have been found from the Sunda Shelf region of Indonesia (Aziz & Janjoux, 1984), where 19 species of asteroid sea stars were recorded around Pulau Bodgaya and Pulau Sipadan, Sabah, Malaysia (George & George, 1987). There appears to be little endemism among asteroids on oceanic islands of this region (Marsh, 1974; Yamaguchi, 1975), and this could be due to good larval dispersal and consequent lack of geographical isolation.

This was the first study of the diversity and abundance of the sea star in the Malaysian waters of the central South China Sea. Our objectives were to determine the diversity, abundance, habitat and morphology of the sea stars from Gugusan Beting Patinggi Ali (South Luconia Shoals), Gugusan Beting Raja Jarom (North Luconia Shoals), Terumbu Semarang Barat Kecil (Louisa Reef), Terumbu Semarang Barat Besar (Royal Charlotte Reef) to Gugusan Pulau Layang-Layang (Swallow Reef), collected during the ROSES (The Research On The Seas And Islands Of Malaysia) Expedition 2004.

Materials and Methods

Fifteen reefs, located in the central South China Sea were surveyed in Malaysian waters (Fig. 1). The observations of species found in the study sites were done using SCUBA diving and reef walks at low tide. The survey was conducted both during night and day since some of the sea star species are nocturnal.

Wandering transect was applied in this study due to the limitation of time available in this expedition. Diver will swim along the surveyed reefs & area coverage of each sampling sites were recorded using the GPS (Global Positioning System) and estimated. Distances of area surveyed were calculated and the numbers of same species were converted into Relative Abundance unit (individual per 100m²). This method was also applied to the reef walks at low tide which distance of area surveyed were recorded and the numbers of sea stars counted in each survey was standardized to individual per 100m².

The morphology, habitat types (substrate & depth) and total number of sea stars were recorded. The sea stars, which could not be identified underwater, were brought to the laboratory for further morphological investigation (arm, central disc, madreporite, spines, mouth, tube feet and ambulacral grooves). Further description on the morphology of the sea stars and photographic records were made. All the samples were preserved in 70% ethanol (Lincoln & Sheals, 1979) and stored in References Collection Museum, Centre For Marine & Coastal Studies (CEMACS), Universiti Sains Malaysia.

Results and General Discussion

The survey results are shown in Table 1. In total, six families, 12 genera and 20 species were recorded in the study sites. The dominant family found was Ophiasteridae (12 species) followed by Echinasteridae (Three species). The most common genus observed was *Linckia* spp. (Four species), *Fromia* spp. (Three species) and *Echinaster* spp. (Three species). The most abundant sea star found was *Choriaster granulatus* (Appendix: D), which inhabited the sandy bottom and rocky areas in 12 surveyed reefs. *Echinaster luzonicus* (Appendix: B), *Culcita novaeguineae* (Appendix: E), *Linckia laevigata* (Appendix: J), *Linckia guildingi* (Appendix: K), *Linckia multiflora* cf. (Appendix: L) and

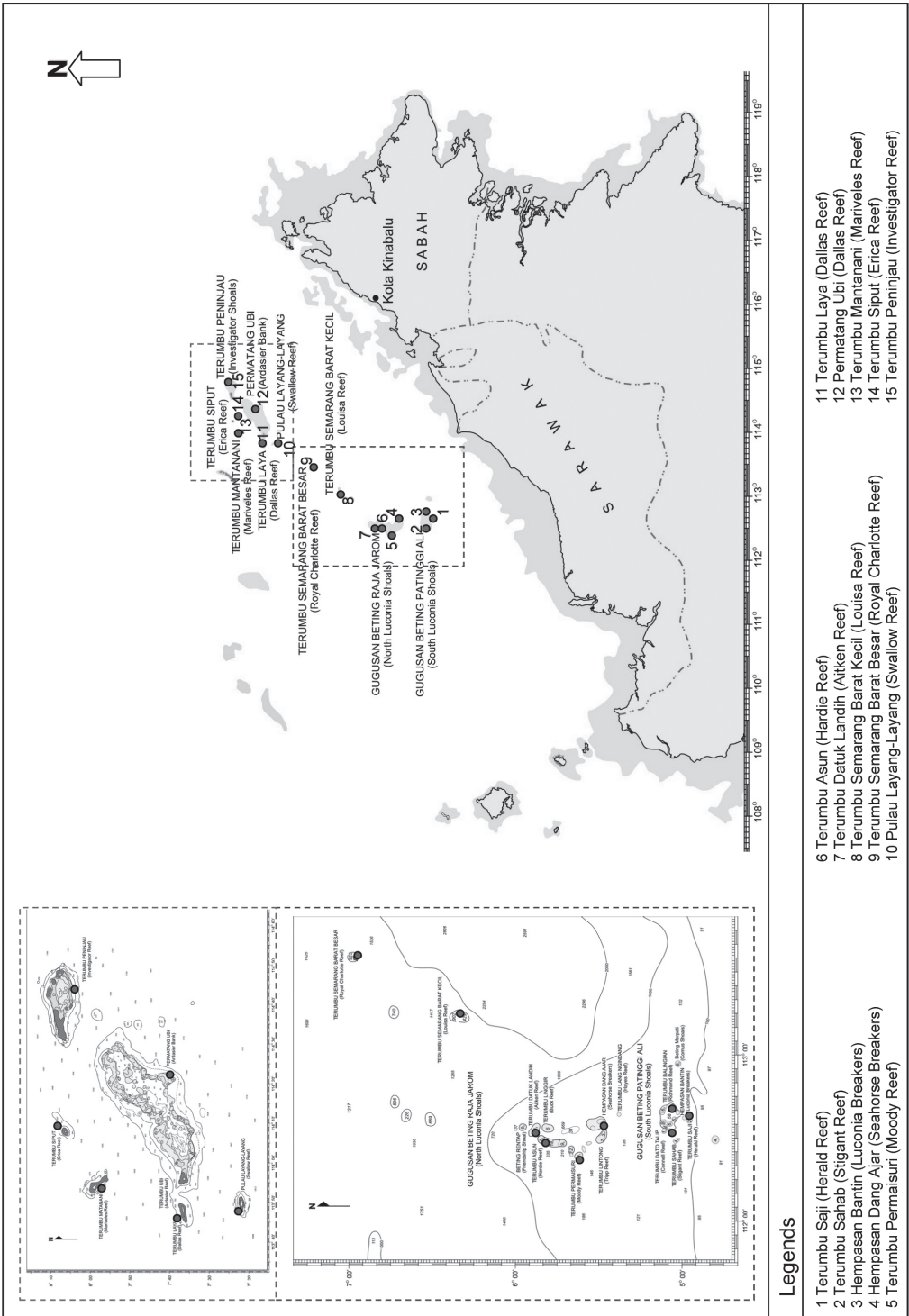


Table 1. This table shows the diversity and abundance of the sea star (Asteroidea) from the different reef of the central South China Sea.

No	Species	Relative Abundance (Individual per 100m ²)																
		Hempasan Bantin	Terumbu Saji	Terumbu Sahap	Terumbu Dang Ajar	Terumbu Datuk Landih	Terumbu Asun	Terumbu Pernaitsuri	Terumbu Semarang Barat Kecil	Terumbu Semarang Barat Besar	Terumbu Peninjau	Terumbu Siput	Terumbu Mantanani	Terumbu Laya	Pulau Layang-Layang	Permatang Ubi	Total	
Family Acanthasteridae																		
1	<i>Acanthaster planci</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	
Family Asteropeidae																		
1	<i>Asteropsis carinifera</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	
Family Echinasteridae																		
1	<i>Echinaster callosus</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2	
2	<i>Echinaster luzonicus</i>	4	2	3	1	0	0	0	0	5	0	4	0	5	0	1	25	
3	<i>Echinaster sp.</i>	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	2	
Family Mithorodiidae																		
1	<i>Mithrodia fisheri</i>	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	2	
Family Ophidiasteridae																		
1	<i>Fromia monilis</i>	0	0	0	0	1	0	0	0	0	0	3	0	0	0	0	4	
2	<i>Fromia indica</i>	0	1	0	0	0	0	0	0	0	2	1	0	0	0	0	4	
3	<i>Fromia sp.</i>	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3	
4	<i>Lincxia laevigata</i>	5	0	0	1	2	0	0	3	7	6	10	0	9	5	0	48	
5	<i>Lincxia guildingi</i>	3	0	0	0	0	0	0	0	1	1	3	0	1	2	0	11	
6	<i>Lincxia sp. cf. L. multiflora</i>	3	1	0	0	2	1	1	0	1	0	5	2	2	3	5	26	
7	<i>Lincxia multiflora</i>	1	0	0	0	0	0	0	0	0	7	9	0	6	0	0	23	
8	<i>Neoferdina offreti</i>	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	
9	<i>Nordia sp. cf. L. gomophia</i>	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	3	
10	<i>Leiaster speciosus</i>	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	2	
11	<i>Leiaster sp.</i>	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	3	
12	<i>Ophidiaster hemprichi</i>	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	
Family Oreasteridae																		
1	<i>Choriaster granulatus</i>	3	0	1	2	1	1	2	0	4	3	0	5	0	1	2	25	
2	<i>Cultita novaeguineae</i>	5	0	0	0	2	1	0	1	0	4	8	0	0	0	2	23	
Total Genus		5	4	3	3	5	3	2	3	3	6	10	2	2	3	4		
Total species		8	4	3	4	6	3	2	3	5	9	16	2	5	6	4		

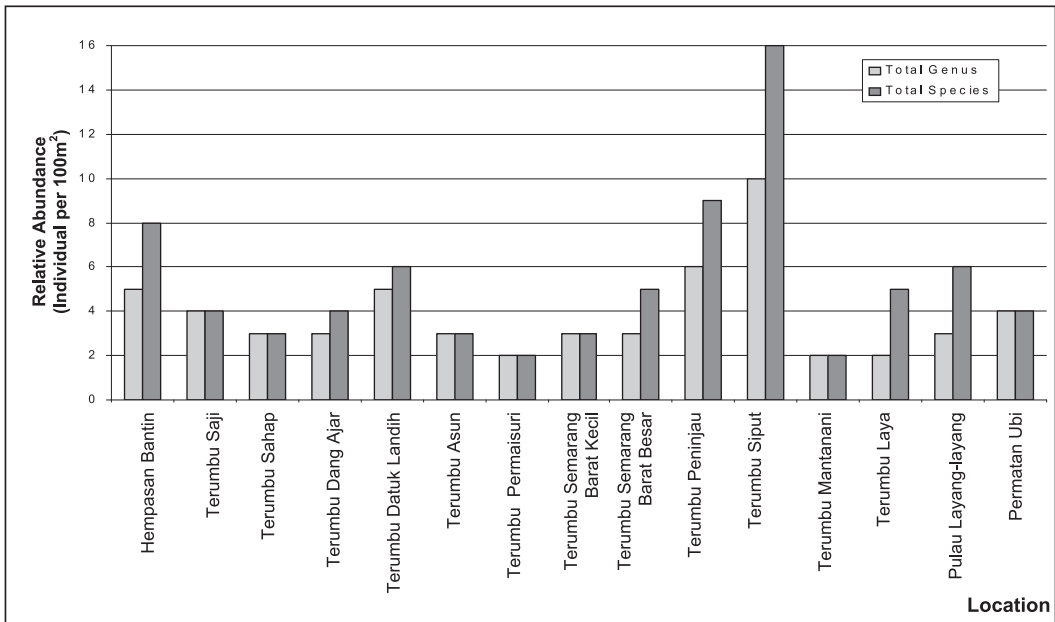


Fig. 2. The total number of genera and species of the sea stars (Asteroidea) collected from the different reefs during the ROSES Expedition 2004.

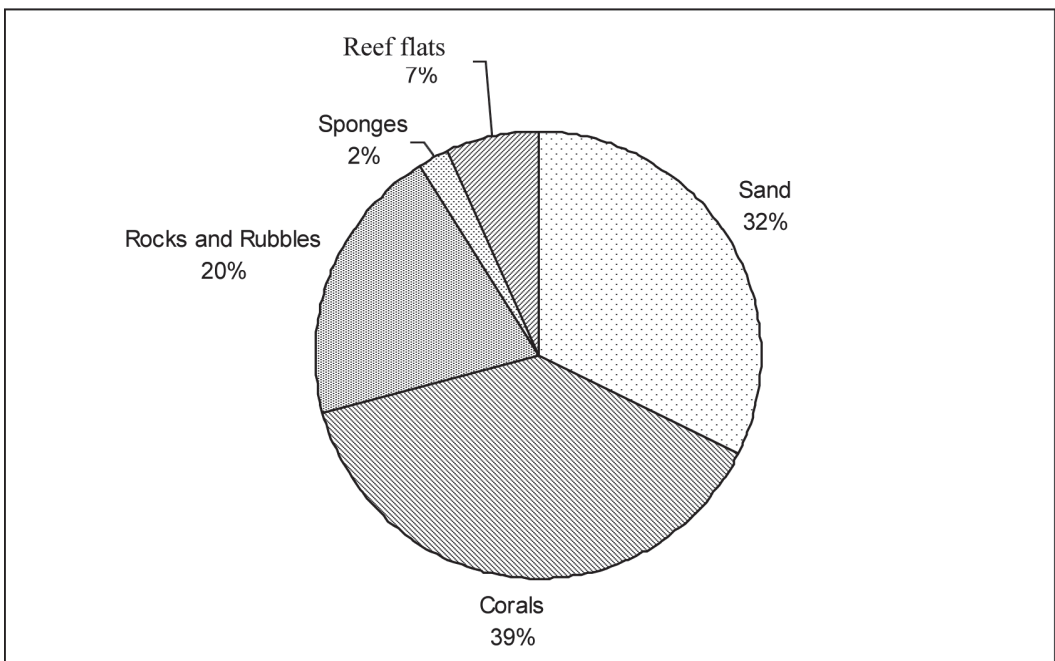


Fig. 3. The percentage of the sea star samples collected from the different types of substrates during the ROSES Expedition 2004.

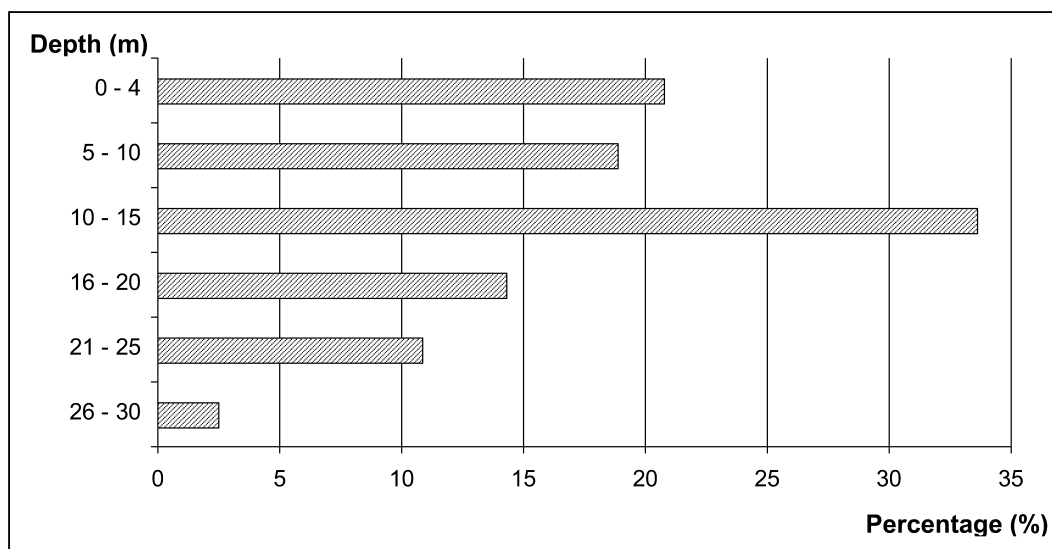


Fig. 4. The percentage of the sea star samples collected from the different depths of sampling locations during the ROSES Expedition 2004.

Linckia mutifora (Appendix: M) were considered high density species because they were found in six to eleven sampling locations and the number of individuals collected was high (11 - 48 samples per species per location). The other sea stars species found were considered rare species because they were only reported in one to three reefs per species. The numbers of individuals of those species were low (1 - 4 samples found in whole expedition).

Terumbu Siput (Erica Reef) exhibited the highest biodiversity of sea star populations amongst all the reefs surveyed (Fig. 2). Ten genera of sea stars were found here. Terumbu Peninjau (Investigator Reef) and Hempasan Bantin (Luconia Breakers) also exhibit high diversity of sea stars, with six genera and nine species reported in Terumbu Peninjau (Investigator Reef), and five genera and eight species in Hempasan Bantin (Luconia Breakers). Terumbu Sahap (Stigant Reef), Terumbu Asun (Hardie Reef), Terumbu Permaisuri (Moody Reef), Terumbu Semarang Barat Kecil (Louisa Reef) and Terumbu Mantanani (Mariveles Reef) had a low density of sea stars and only one to four species were recorded per sampling site.

Three sea star species [*Echinaster* sp. (Appendix: C), *Fromia* sp. (Appendix: I) and *Leiaster* sp. (Appendix: Q)] were classified only to the genus level by the morphology characteristics. Further analysis is being carried out to confirm the species name using DNA analyses.



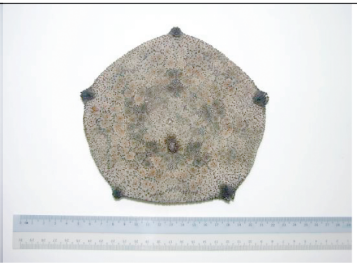
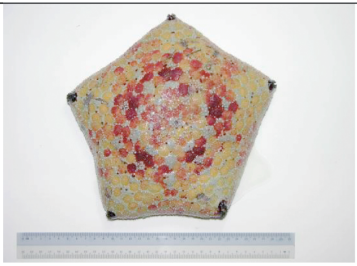

The majority of the sea stars were found on coral (39.0 %), followed by the sandy substrate (32.0 %) and rocks and rubbles (20%) (Fig. 3). 33.6 % of the sea star samples were collected from the depths between 11 m to 15 m and 20.8 % was found in the depths between 0 m to 5 m (Fig. 4).

C. novaeguineae (Appendix: C) does not display the typical five-armed star shape but had a pentagonal outline; hence, it is frequently mistaken for a sea urchin. It is highly variable in colour, ranging from red to green and brown. We observed ten patterns of colour variations from the total samples (23 samples) of *C. novaeguineae* collected (Table 2). Two colour patterns (Colour patterns A & B) were considered the common pattern and the other was specific to each sampling location (Table

Table 2. Number of sea star *Culcita novaeguineae* samples collected from the different reefs of sampling location according to the colour patterns.

Colour patterns	Sampling Location (Number of samples collected)
<p>A</p> 	<p>Hempasan Bantin (3), Terumbu Peninjau (1), Terumbu Siput (1).</p>
<p>B</p> 	<p>Hempasan Bantin (1), Terumbu Datuk Landih (1), Terumbu Siput (2).</p>
<p>C</p> 	<p>Hempasan Bantin (1), Terumbu Datuk Landih (1).</p>
<p>D</p> 	<p>Terumbu Asun (1)</p>
<p>E</p> 	<p>Terumbu Peninjau (1)</p>

Continue Table 2

F		Terumbu Siput (3)
G		Terumbu Siput (1)
I		Terumbu Siput (1)
J		Terumbu Peninjau (3)
K		Permatang Ubi (2)

2). We also observed two colour variations in sea star *L. multifora*, the common colour which had red spots with whitish skin, and the rare colour pattern which had dark purple spots with grey skin. Further confirmation and research with expert scientists will be carried out to separate species according to colour morphology.

Conclusion

Six families, 12 genera and 20 species of sea star were reported in this survey which covered most of the reefs in Gugusan Beting Patinggi Ali (South Luconia Shoals), Gugusan Beting Raja Jarom (North Luconia Shoals), Terumbu Semarang Barat Kecil (Louisa Reef), Terumbu Semarang Barat Besar (Royal Charlotte Reef) and Gugusan Pulau Layang-Layang (Swallow Reef), located at the central part of the Sarawak, the South China Sea.

Numbers of species (20 species) found in this study was very similar to the study done by Purwati & Lane (2004) which identified 27 sea star species belonging to 9 families from material collected in the Anambas and Natuna Archipelagos (Southern South China Sea) during The Anambas Expedition 2002. Species account showed that 11 species of sea stars recorded in the central South China Sea (this study) didn't occurred in the southern South China Sea (Purwati & Lane, 2004) indicated the unit distribution pattern of sea stars in the South China Sea and more research need to be carried out to map the distribution patterns in the future.

This 42 days expedition was unable to cover all the reefs in the surveyed areas and the methods used were mainly qualitative, since it was unrealistic to hope to carry out quantitative surveys on all sea stars in the time available (George & George, 1987). We hope to expand our geographic range in the next expedition to discover more sea star species in the central South China Sea due to the large areas of the South China Sea which remain relatively unexplored biologically and it is likely that additional records and new sea star species await discovery (Lane *et al.*, 2000).

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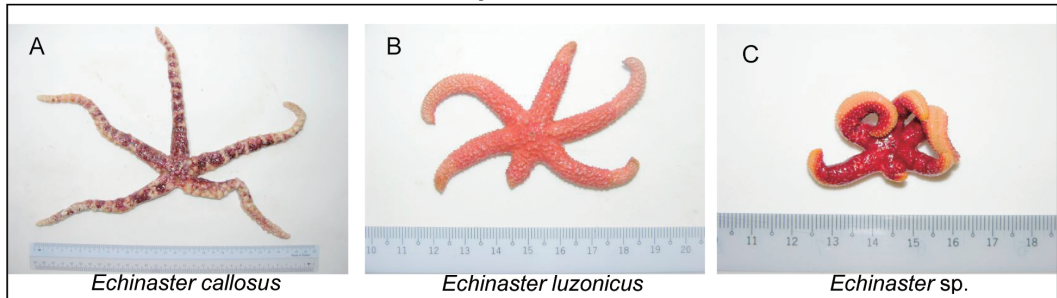
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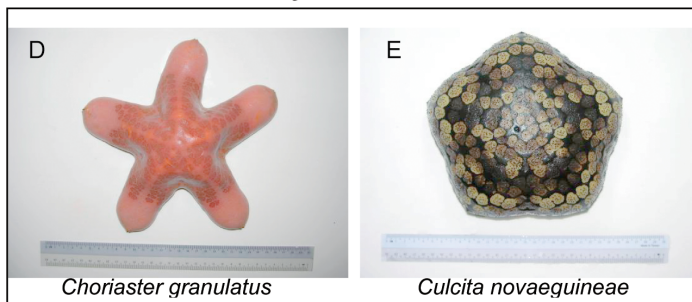
Appendix

The morphology and variations of the sea star (Asteroidea) collected from the different reefs during the ROSES Expedition 2004.

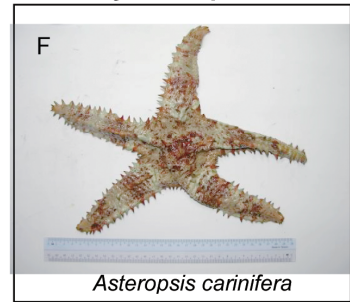
Family Echinasteridae



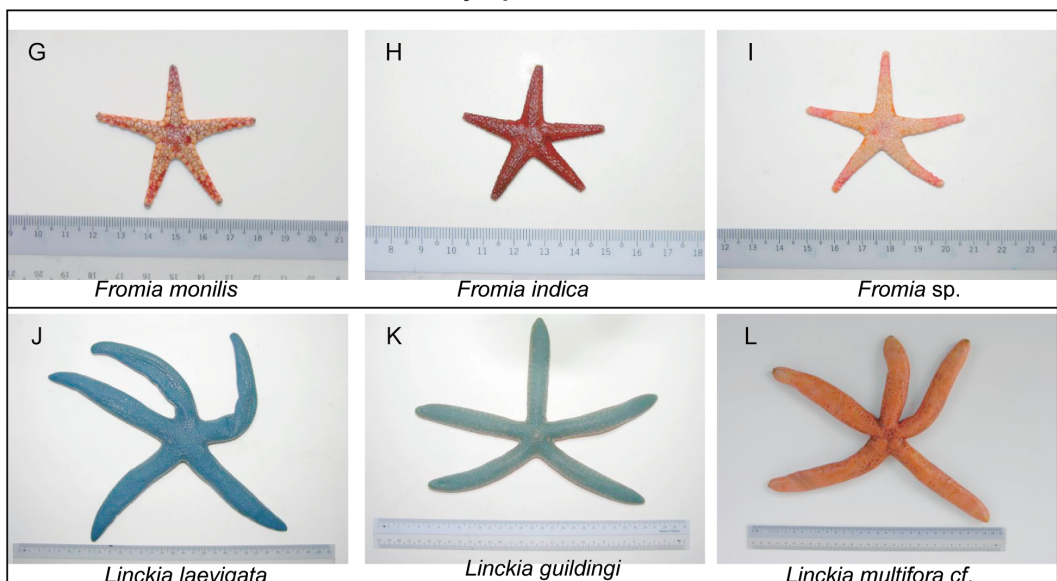
Family Oreasteridae

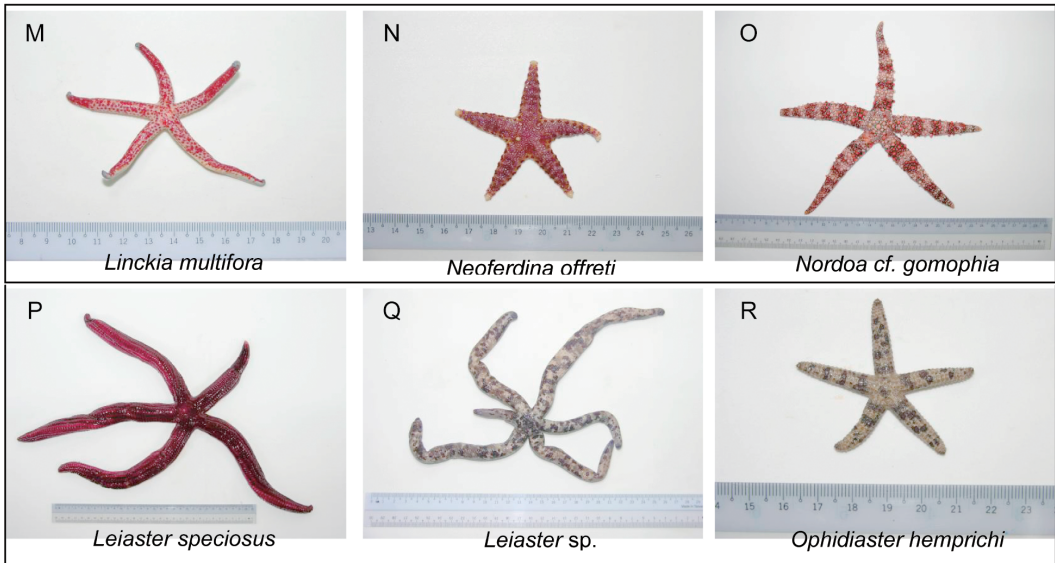
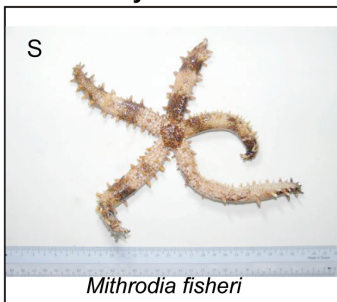


Family Asteropseidae



Family Ophidiasteridae



**Family Mithrodiidae****Family Acanthasteridae**